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## INTRODUCTION

□ **MICROGRID** : The U.S. Department of Energy states that a Microgrid [1] is :

- A group of interconnected loads and distributed energy resources (DER) with clearly defined electrical boundaries
- A single controllable entity with respect to the grid
- An entity which can connect and disconnect from the grid and enable it to operate in both grid-connected or island mode.



Figure 1. Microgrid Model [1]  
(Representative DoD Facility)

## RESEARCH CONTRIBUTION

□ **Laboratory-scale microgrid test-beds** would have an important role in next few years to :

- Test and validate emerging smart grid technologies
- Achieve a successful transition in modern power system operations.
- **Microgrid Test-Bed at Penn State Harrisburg** aims to :
  - Promote the use of clean energy and distributed generation in a consumer interactive power grid
  - Innovate reliable multi-agent based control methodologies for microgrid systems
  - Implement novel protection schemes during various faults (external or internal to the microgrid)
  - Use co-simulation platform to test the scalability of the system with hardware-in-the-loop capabilities, and carry out power flow studies

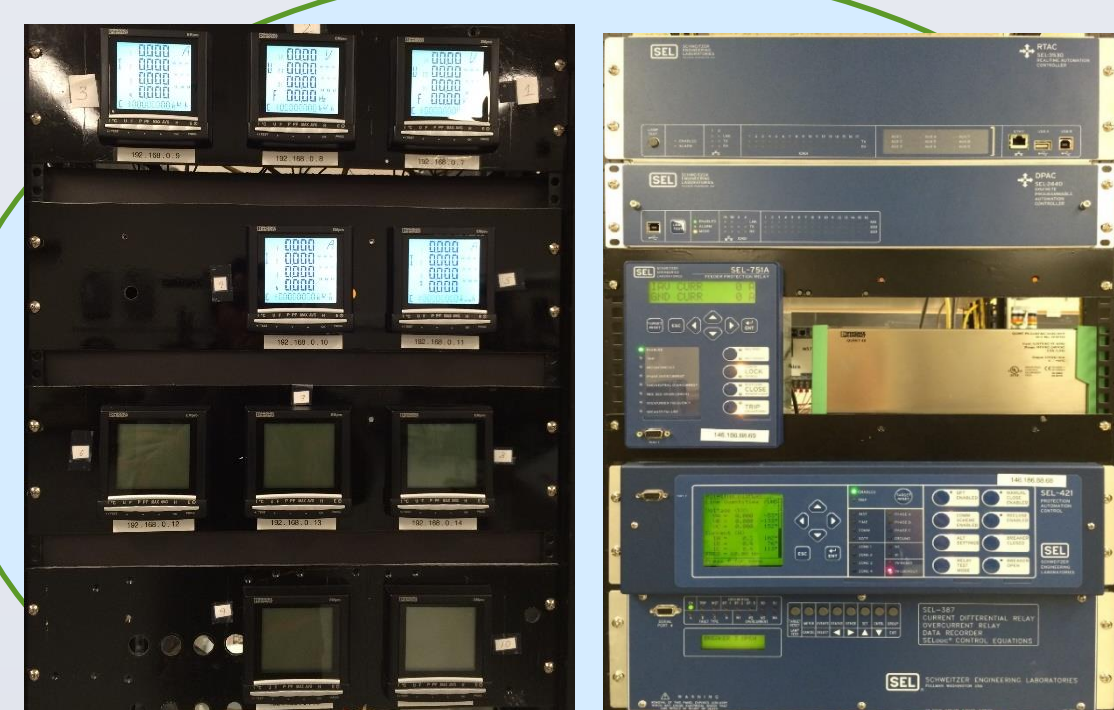


Figure 2. Smart Metering and Advanced Digital Protection System



Figure 3. Different Types of Loads

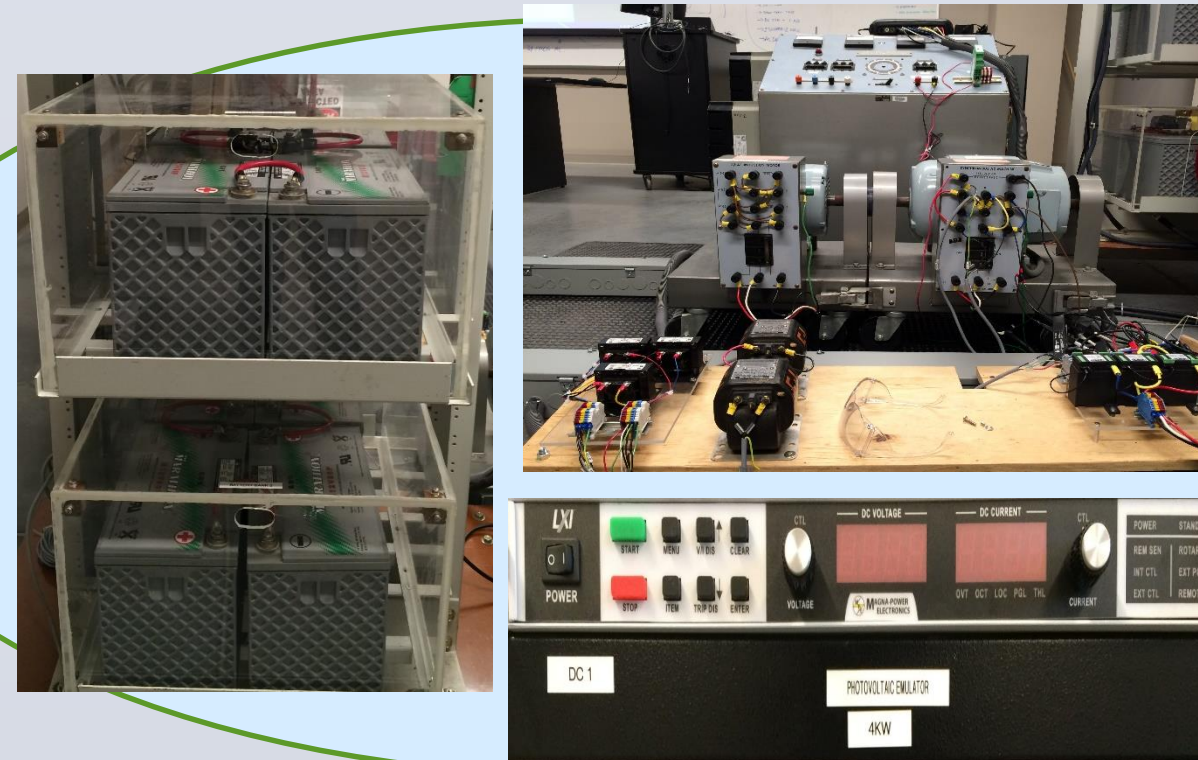


Figure 4. Renewable Energy and Distributed Generation

## PROPOSED MULTI-AGENT BASED INTELLIGENT DISTRIBUTED CONTROL

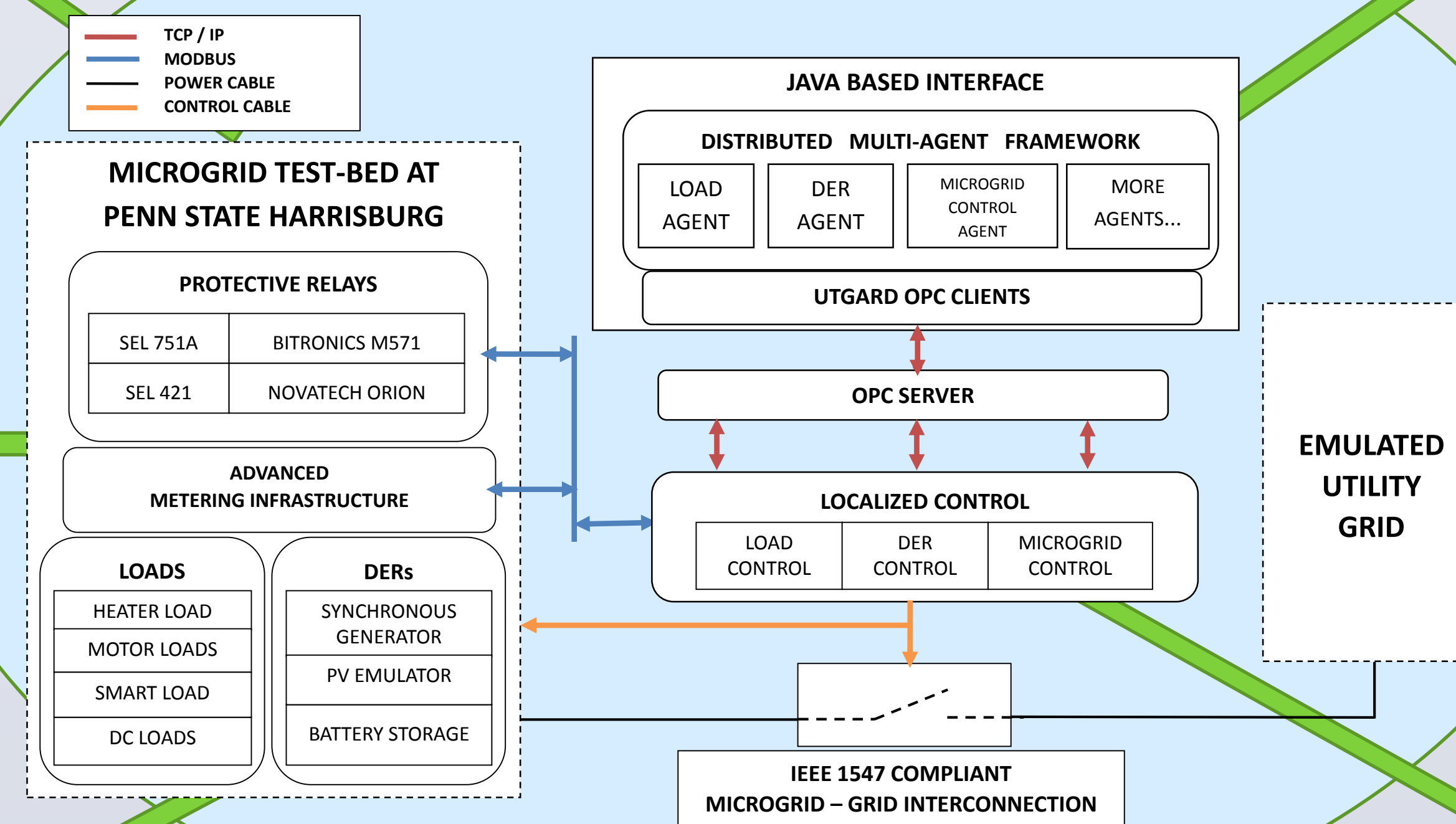


Figure 5. Proposed Multi-Agent Based Intelligent Distributed Control

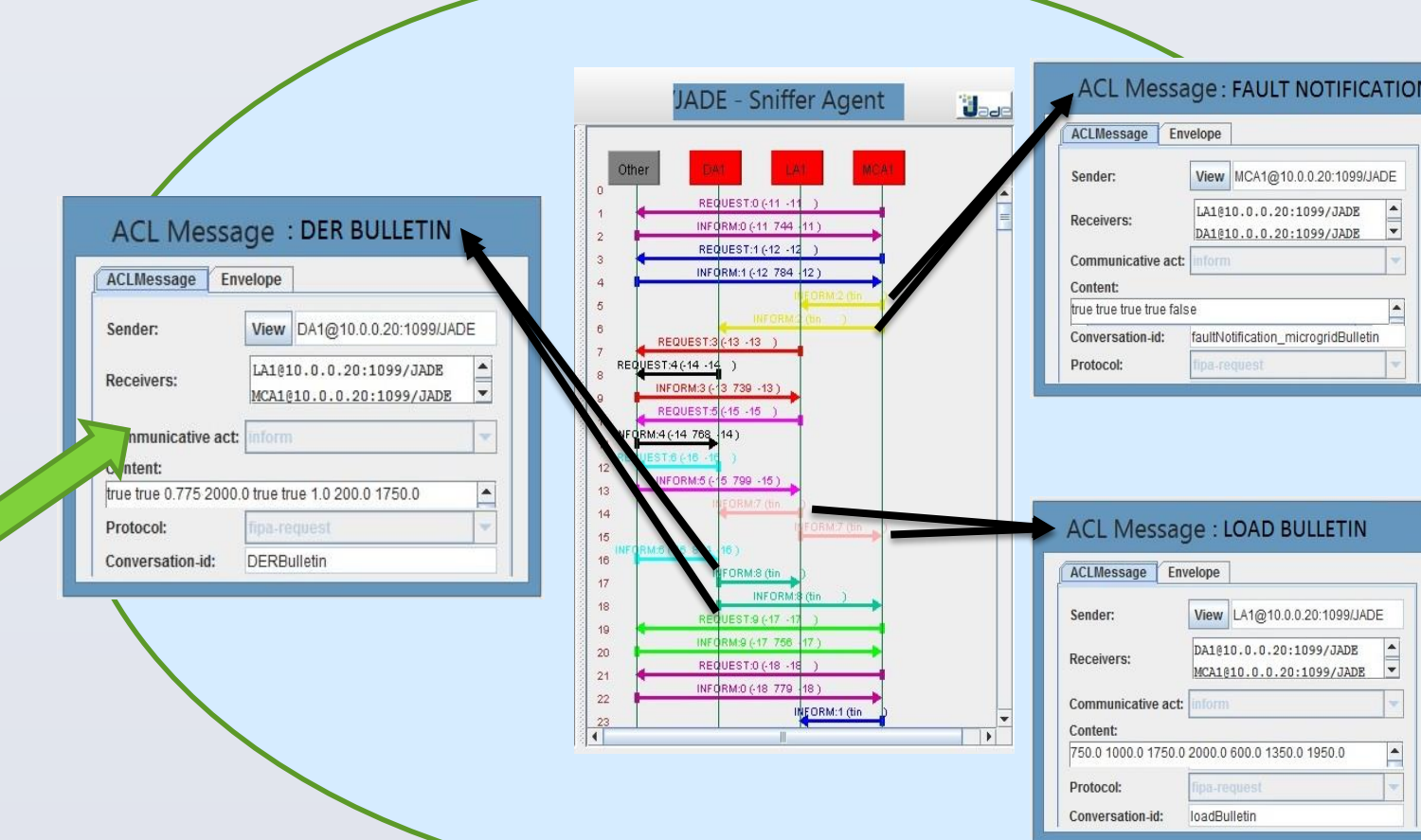


Figure 6. ACL Message Communication between Intelligent Agents



Figure 7. Utility Grid

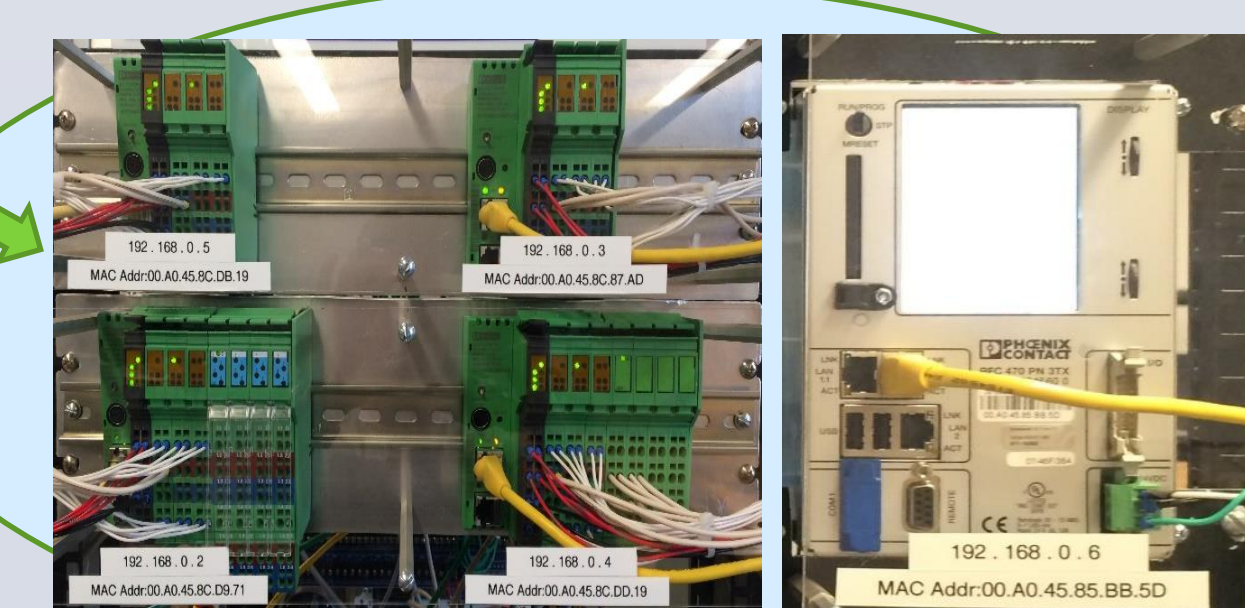


Figure 8. Localized Control using IEC 61131

## RESULTS AND DISCUSSION

- Multi-Agent based control was successfully implemented to ensure reliable microgrid operations including seamless islanding during faults, grid-connected / islanded mode operation, etc.
- The importance of industry standards, specifications and protocols in microgrid implementation was studied.

## ACKNOWLEDGEMENTS

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## FUTURE WORK

- Implementation of short-term load and energy forecasting using artificial neural networks
- Energy optimization and economic dispatch using pricing signals in real-time market
- Provision of black-start capabilities in case of emergency islanded situations

## REFERENCES

[1] Tristan Glenwright, "Introduction to Microgrids". [Online]. Available: <http://www.smartgrid-live.com/wp-content/uploads/2012/12/Introduction-to-Microgrids-by-Tristan-Glenwright.pdf> [2015].